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HYDROLOGIC ASSESSMENT OF THE BIG CYPRESS NATIONAL PRESERVE:

A WATER RESOURCES ANALYSIS FOR THE GENERAL MANAGEMENT PLAN (GMP) AND MINERALS MANAGEMENT PLAN (MMP)

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PREFACE

Water is an important resource that must be considered in any planning process. Knowing where it comes from, where it goes, how much there is, and how it varies both in the short term and in the long term is necessary for intelligent decision-making. Equally important are its intimate relationships with all other physical components in the planning base and the underlying policy guidelines related to its utilization and/or protection.

The question of utilization versus protection within the Big Cypress was determined in 1974 with the establishment of the Big Cypress National Preserve (Public Law 93-440) to ensure the "preservation, conservation, and protection of the natural, scenic, hydrologic, floral, faunal, and recreational values of the Big Cypress watershed, and to provide for the enhancement of public enjoyment thereof." However, the enabling legislation also provides for the continuation of certain land-use activities such as oil, gas, and minerals exploration and extraction, and public access for hunting and use of off-road vehicles.

Prior to the establishment of the preserve, significant intrusions were made into the hydrologic system of the area which altered the natural hydrologic cycle both in patterns of flow and in the timing of these flows. The Tamiami Trail (U.S. 41), Turner River Road (S.R. 29), Alligator Alley (S.R. 84), and physical components of oil and gas operations are the major intrusions. Other lesser intrusions are the Loop Road, the Dade-Collier Training and Transition Airport, about 300 small hunting camps, and tracks left by the use of off-road vehicles.

National Park Service policy regarding the Big Cypress is to maintain and/or restore the water resources in the Big Cypress National Preserve to as near-natural hydrologic conditions as possible. Balancing this objective with the legislatively permitted activities in the preserve presents a paradox in planning and management.

I. INTRODUCTION

The Big Cypress Swamp is a recognized physiographic province in southwestern Florida located geographically west of the Everglades (Figure 1). With the accelerated acquisition of hydrologic data in south Florida in the 1960's, the importance of Big Cypress as a source of recharge to the shallow aquifers of south Florida and to the integrity of the water resources in the western part of Everglades National Park became readily apparent. In recognition of this and other unique features of the swamp, Congress established an area of 570,000 acres (231,000 hectares) as the Big Cypress National Preserve in order to preserve and protect this important natural resource.

The preserve comprises vegetation types representing both tropical and temperate zone species. Patterns in which these vegetative communities occur, and their related wildlife species, are largely determined by and are dependent upon the water regimen of the area. The combination of flat topography and gentle, almost imperceptible land slopes creates an overland sheet flow during the wet season in summer and early fall. During the dry season in winter and spring, natural surface water flows are confined to the lower elevations of strands and sloughs.

II. DESCRIPTION OF THE BIG CYPRESS NATIONAL PRESERVE

A. Watershed Boundaries

Early attempts at delineations of the watershed boundaries of the Big Cypress Swamp were made from aerial photographs and field observations by U.S. Geological Survey personnel. They delineated approximate watershed boundaries for three sub-areas for the Swamp extending from Levee 28 on the east to Naples on the west. Generalized patterns of flow within these sub-areas were also subsequently delineated.

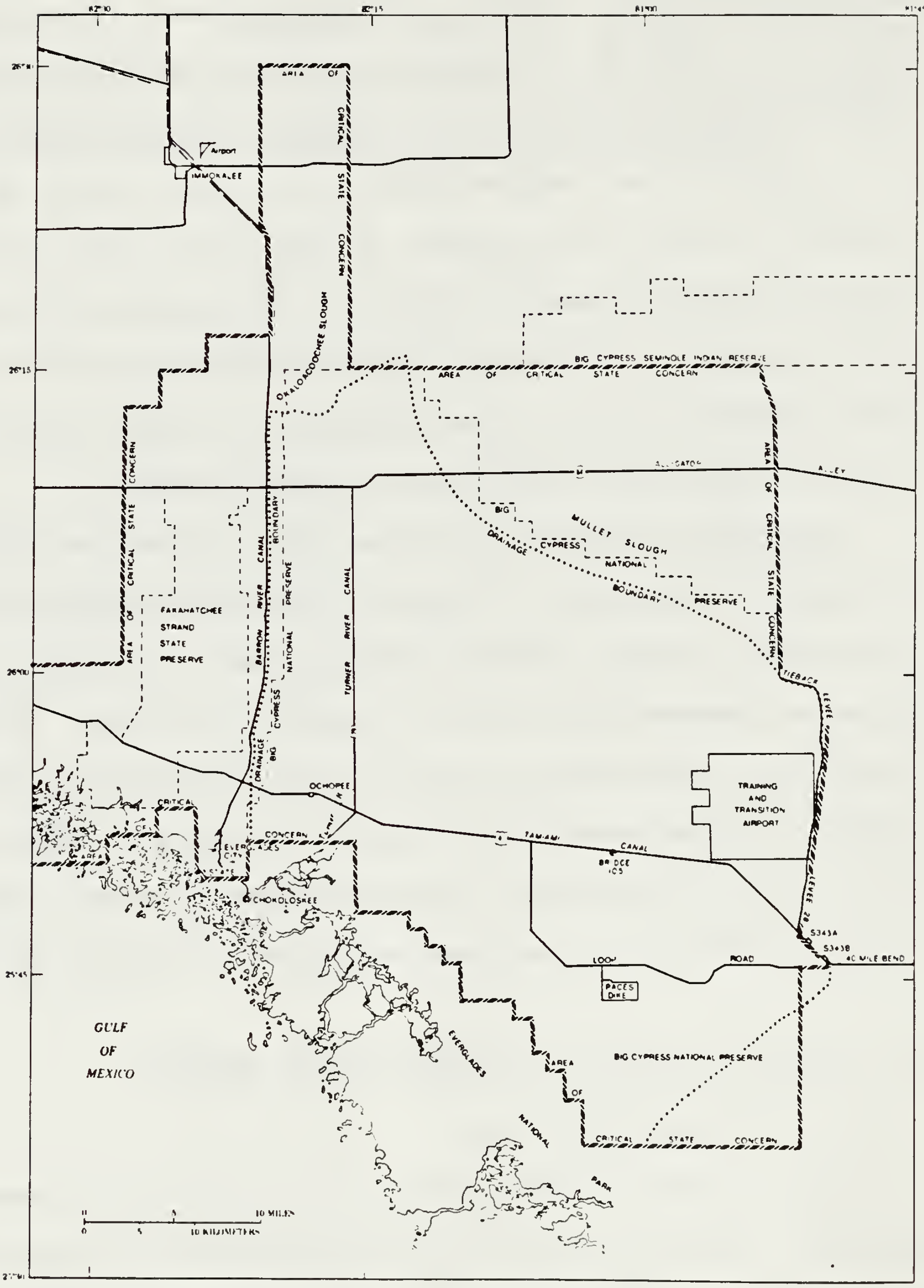


Figure 1. Drainage boundary of the Big Cypress National Preserve.

Since then, orthophotomaps have been prepared by the U.S. Geological Survey containing a photo rendition of the land surface as well as numerous land elevations, previously unavailable, for analysis of drainage patterns. These orthophotomaps, along with new infrared color photography obtained in March 1984, were used to define the drainage basin shown in Figure 1. The designated boundary between the Big Cypress drainage and the Everglades drainage to the northeast was compared with that for the Everglades basin currently being developed independently by James H. Hartwell, hydrologist, of Miami, Florida. Boundary determinations from the two assessments were generally within a mile of one another, which is excellent in view of the extremely flat topography. These minor differences were mutually reconciled so that both maps would show compatible boundaries. During periods of high water there is a common water surface across the divide between the Big Cypress and Everglades drainages, but the transfer of water from one basin to another is probably negligible.

In the northwest corner of the preserve, the effective drainage boundary is the Bear Island Road, an improved all-weather road running eastward from State Route 29 to the Bear Island area. According to a local resident (Jack Price, personal communication) this road has not been inundated since its improvement in the 1960's. However, the road has 42-inch and 48-inch corrugated pipe culverts in five locations in the first 3.4 miles from State Route 29. Although these culverts provide a hydraulic connection between the Okaloacoochee Slough and East Hinson Marsh, the transfer of water from the slough to the marsh is not believed to be significant. Measurements obtained by the U.S. Geological Survey during a period of high water November 18-20, 1969, show a

flow rate of 215 cubic feet per second (cfs) from the Okaloacoochee Slough as it enters the Barron River Canal, while the Turner River Canal carried a total flow of only 69 cfs, presumably originating from the East Hinson Marsh area.

The significance of this redefined drainage boundary for planning will be discussed in a subsequent section of this report.

B. Hydrology

The Big Cypress National Preserve is essentially a self-contained hydrologic unit. Only three small areas, representing approximately three percent of the preserve, receive flows from external drainages. Less than five square miles of the 2,400 square miles that constitute the preserve are in the Okaloacoochee drainage; about 30 square miles are in the Mullet Slough component of the Everglades drainage; and approximately 40 square miles in the southeastern corner of the preserve fall along the western boundary of the Shark River Slough. The remaining 97 percent of the preserve reacts in response to rainfall over the area.

A detailed evaluation of the hydrology of the Big Cypress area was made by the U.S. Geological Survey prior to the establishment of the preserve. As such, it documents the hydrology of the preserve at the time of acquisition and supplies a baseline against which to assess changes resulting from management practices. The following description of the hydrology of the preserve has been adapted from these reports.

The Big Cypress National Preserve is largely inundated during the rainy season, generally May through October. Normal monthly rainfall for the Everglades and southwest Florida areas are given in Table 1.

Table 1. Composited monthly rainfall data for 12 U.S. Weather Bureau stations near Big Cypress National Preserve.

Month	Precipitation (inches)	Month	Precipitation (inches)	Month	Precipitation (inches)
Jan.	1.63	May	4.32	Sept.	8.47
Feb.	1.91	June	8.29	Oct.	4.39
Mar.	2.65	July	8.18	Nov.	1.53
Apr.	2.98	Aug.	7.47	Dec.	1.42

Nearly 80 percent of the rain normally falls during a 6-month rainy season. Rainfall averages 53 inches per year, but it has ranged from 35 inches to 80 inches per year. Summer rains are usually short, intense, and frequent. Winter rains usually result from frontal systems and are of longer duration and of less intensity. Hurricanes occur most frequently in September and October and usually bring torrential rainfall.

During the rainy season, shallow depressions fill with water, and, because of the poor drainage, water stands on the land until it evaporates or slowly drains off through sloughs or strands. Thus, as much as 90 percent of the preserve is inundated to depths ranging from a few inches to more than 3 feet at the height of the rainy season. As the dry season begins, the water level starts to recede. The recession normally continues into May, when perhaps 10 percent of the preserve is covered by water in ponds and sloughs.

Although the surface of the preserve seems flat with no well-defined stream systems, flows generally follow bedrock undulations that run mostly north to south and range in relief from approximately 1 foot to as much as 10 feet. Marshy sloughs occupy the shallower undulations, and cypress strands grow in the deeper ones. These relatively low

channels tend to control surface water flows, since the water table is below the crests of the undulations most of the time. However, even during high water when there is sheet flow over extensive areas, the bedrock flows still carry a relatively large volume of the water.

The preserve is underlain by an extensive shallow aquifer extending from the vicinity of Forty Mile Bend to the west coast and covering almost all of Collier County and the upper part of Monroe County. It is the prime source of fresh water supplies in Collier County and adjoining parts of Lee and Hendry Counties. The aquifer, which has a thickness of about 130 feet in western Collier County, becomes progressively thinner to the east, where it eventually disappears in the vicinity of Forty Mile Bend. Throughout much of the preserve, the limestone of this shallow aquifer is within 10 feet of the surface.

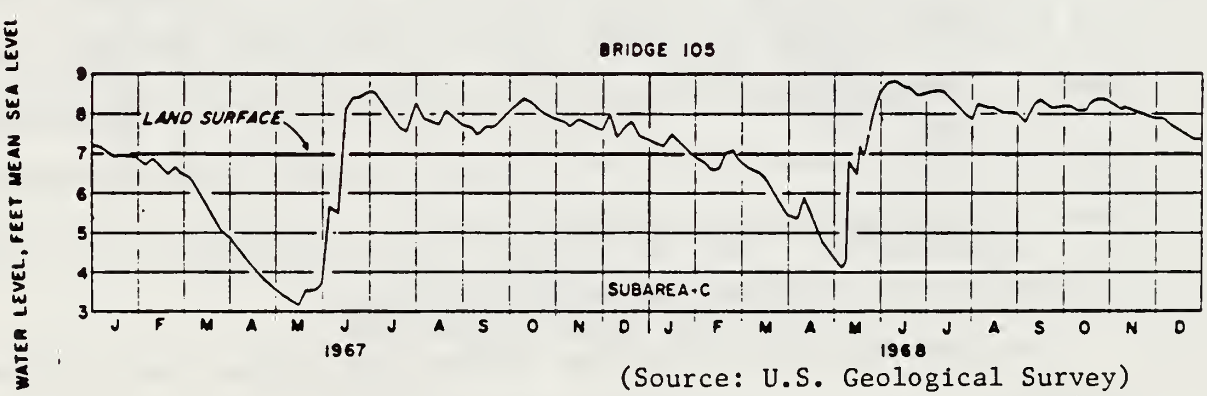
Although the aquifer is non-artesian, it contains beds and lenses of sandy clay and of fine sands of low permeability, which tend to retard the circulation of water in the aquifer. Generally, the limestone parts of the aquifers are the important water-yielding sections because they are riddled with solution holes and therefore are highly permeable. However, nearly everywhere, especially in the preserve, the upper part of the limestone section is hard and dense and of lower permeability than the lower sections. This low permeability restricts the ability of shallow canals to drain water from storage in the aquifer.

The aquifer is replenished primarily by the infiltration of local rainfall. During the rainy season of June through October, ground-water levels are high, and by May, the usual end of the dry season, water levels normally reach their annual lows. As the rainy season begins,

ground-water levels rise until the aquifer is saturated, and as the water level continues to rise above the ground surface, overland flow occurs in a general south/southwestward direction.

Underlying the shallow aquifer is a thick zone of low yield that forms a confining bed over the Floridan Aquifer, which generally lies at depths over 400 feet. The Floridan Aquifer is artesian, and yields highly mineralized water of as much as 5,000 mg/l of dissolved solids to flowing wells.

Records of water-level fluctuations are available from a few sites, mostly near the outer edges of Big Cypress. Water-level fluctuations for the Tamiami Canal at Bridge 105, 12 miles west of Forty Mile Bend, are representative of the water conditions within the preserve (Figure 2).



(Source: U.S. Geological Survey)

Figure 2. Water level fluctuations for the Tamiami Canal, Bridge 105, January 1967 - December 1968.

The hydrograph reflects the natural cyclical rise in water levels during the rainy season and the decline in levels during the dry season, with inundation persisting for about 7 months in 1967 (June-December) and for nearly the same period in 1968. The rate at which water levels recede after the rainy season is a general measure of the runoff characteristics of the preserve. The recession rates in the channel at Bridge

105 were 0.02 to 0.03 foot per day when the area was inundated, and 0.06 to 0.08 foot per day when levels were generally below the land surface. These rates confirm general observations that runoff from the Big Cypress is slow and that water is stored for extended periods.

The stage-duration curve for the Tamiami Canal observation station at Bridge 105 (Figure 3) indicates the percentage of time that a selected water level is equalled or exceeded at that site. Note that the curve represents water level and not water depth. At times the water level is below ground surface. The total range of water levels during 1952-1969 is 6.2 feet and represents the difference between extremes of flood and drought. During November 1969 to February 1970, the water level ranged from 8.0 to 8.9 feet above sea level, indicating that conditions in the interior of the Big Cypress were wetter than average and that inundation was widespread. At a level of about 7.5 feet, the area of inundation is greatly diminished, and the stage-duration curve reflects the duration of ponded levels and ground-water levels in the general area. At a level of about 7.0 feet, inundated areas decrease to isolated ponds and the major sloughs; levels below 7.0 feet represent declines below the land surface.

The long-term record of flow through the Tamiami Canal outlets within the reach is represented by flow at Bridge 105 (Forty Mile Bend westward to Monroe) (Figure 4). The hydrograph shows the annual cycle of increased discharge during the rainy seasons and reduced discharge during dry seasons. It shows also the wide variation from year to year. Because changes by man have not been significant, the fluctuations in discharge reflect only the differences in the patterns of occurrence and the total annual rainfalls. The discharge during 1940-69 ranged from

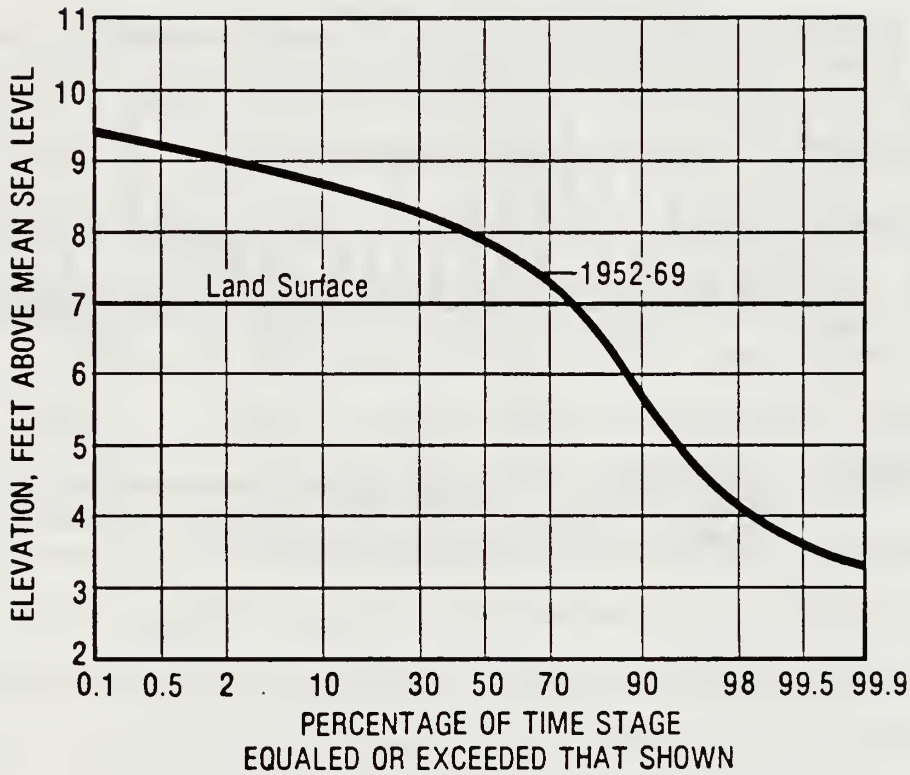


Figure 3. Stage-duration curve for Bridge 105, 1952-69. (Source: U.S. Geological Survey)

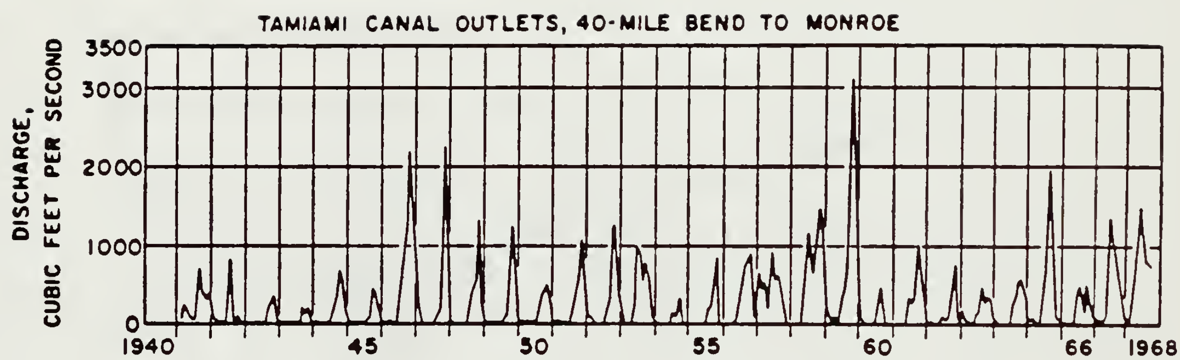


Figure 4. Hydrograph of monthly mean discharge of the Tamiami Canal outlets, Forty Mile Bend to Monroe, 1940-68. (Source: U.S. Geological Survey)

zero during droughts to more than 3,000 cfs after Hurricane Donna in 1960. The discharge is distributed through 29 bridges within about 20 miles. The longest periods of no flow were: 9 consecutive months beginning December 1942; 8 beginning January 1944; 8 beginning January 1950; 8 beginning November 1955; and 8 beginning November 1961.

The annual mean discharge southward through the Tamiami Canal outlets from Forty Mile Bend to Monroe for the total period of record, 1941-69, ranged from about 75 cfs in 1956 to 620 cfs in 1960. The graph in Figure 5 shows the wide variation in discharge possible from year to year. Equally wide variations in discharge occur from month to month, as shown in Figure 6. For example, the discharge through these outlets for October, the wettest month, ranges from 2,700 cfs to 50 cfs and less. Water levels at Bridge 105 can change from 3.5 feet below the land surface to 1 foot above the land surface within a 2-week period.

An analysis of the distribution of flows in the preserve was made on the basis of discharge determined at 253 sites in November 1969. These discharge data and data from Tamiami Canal outlets were used to determine the regional distribution of surface flows within Big Cypress. Figure 7 shows the distribution of flows measured during November 18-20, 1969.

The flow generally increases from north to south; however, flow in the Barron River Canal decreased between Alligator Alley and the Tamiami Canal because water spilled over its banks into adjacent sloughs. North of Alligator Alley, the Barron River Canal picks up flow from the Okaloacoochee Slough. Intermittent records indicate a flow increase of about 150 cfs in that reach during this high-water season.

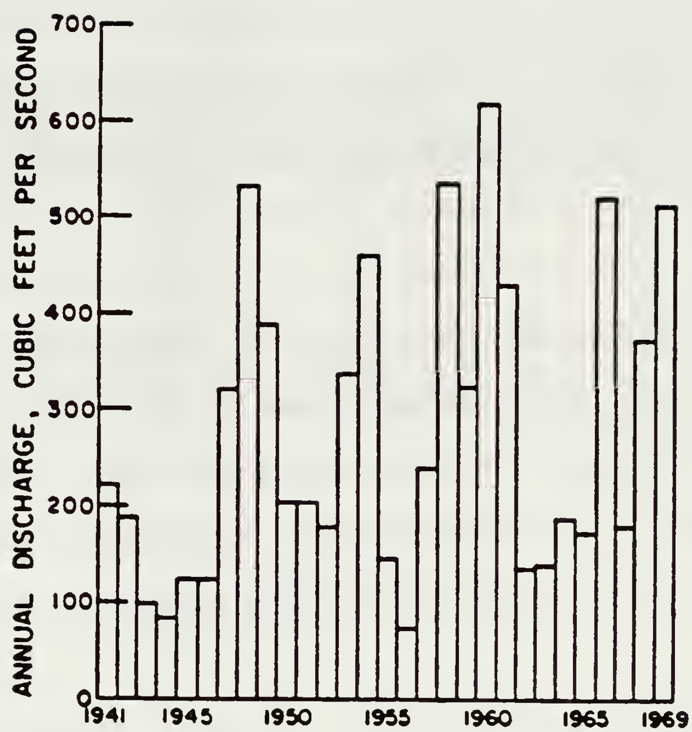


Figure 5. Annual mean discharge for the Tamiami Canal outlets, Forty Mile Bend to Monroe, 1941-69. (Source: U.S. Geological Survey)

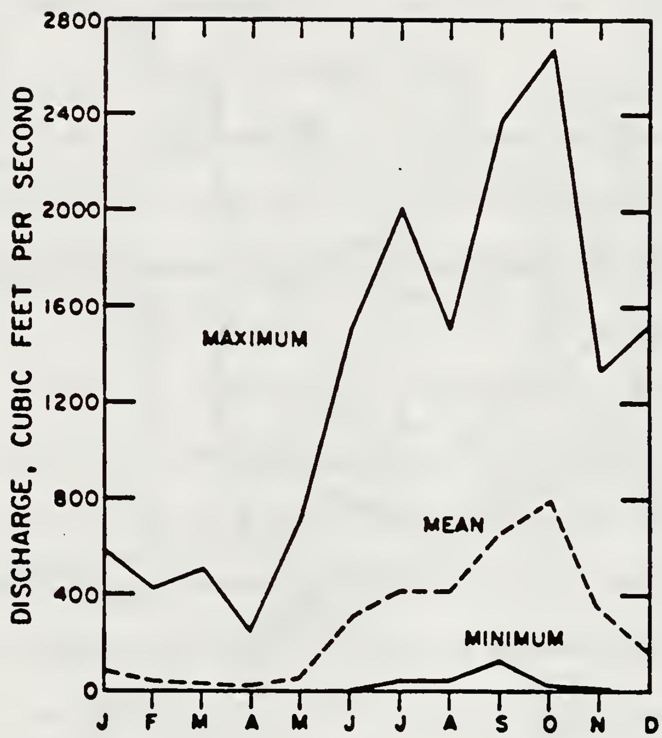


Figure 6. Maximum, mean, and minimum monthly discharge for the Tamiami Canal Outlets, Forty Mile Bend to Monroe, 1941-69. (Source: U.S. Geological Survey)

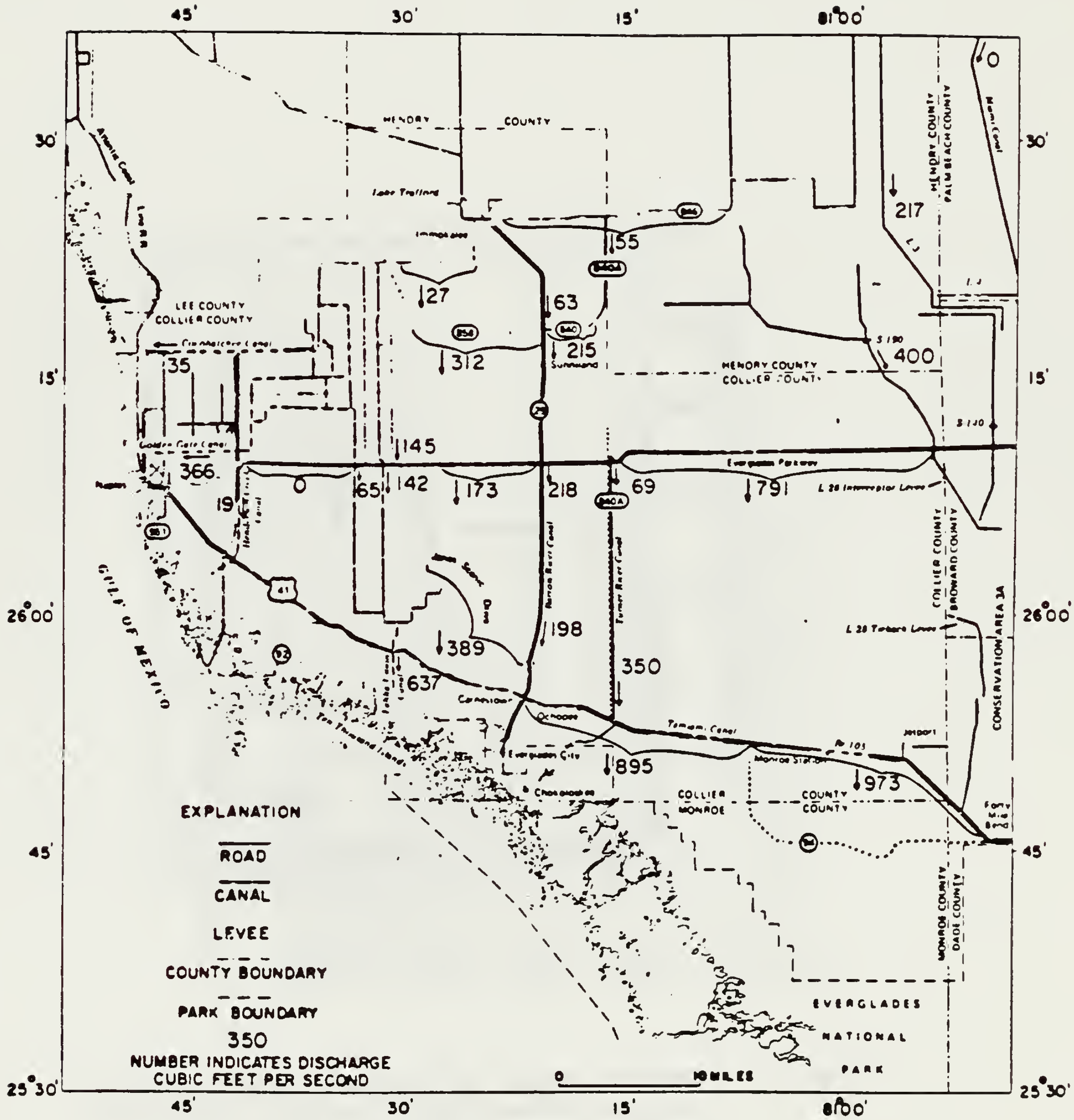


Figure 7. Distribution of flows in the Big Cypress Area, November 18-20, 1969. (Source: U.S. Geological Survey)

The water in Big Cypress National Preserve is relatively unpolluted. This conclusion is based on analysis of water from 15 sites collected from November 1969 through March 1970. These measurements provide background data for comparisons and a base against which to assess changes in water quality. In the preserve, concentrations of nitrogen, phosphorus, total organic carbon, and persistent pesticides, which often serve as indicators of pollution, generally are similar to concentrations in nearby, relatively uninhabited areas but are considerably less than those of nearby urbanized areas.

Nitrogen and phosphorus are the two principal nutrients of aquatic systems. In the Big Cypress National Preserve, concentrations of total nitrogen ranged from 0.19 to 1.85 mg/l (milligrams per liter) and averaged 0.82 mg/l. About 81 percent of the total nitrogen was organic, indicative of a natural environment. Concentrations of total phosphorus (as PO_4) ranged from 0 to 0.33 mg/l and averaged 0.07 mg/l. For comparison, in 1969, concentrations of total nitrogen in the Upper St. Johns River in east-central Florida ranged from 0.55 to 1.4 mg/l and averaged 1.06 mg/l. Concentrations of total phosphorus (as PO_4) in the Upper St. Johns River basin ranged from 0.11 to 0.47 mg/l and averaged 0.26 mg/l. In comparison with the more heavily populated area of nearby Broward County, both the Upper St. Johns River basin and the Big Cypress National Preserve have significantly lower concentrations of nitrogen and phosphorus: average concentrations of total nitrogen and phosphorus (as PO_4) in the canals of Broward County were 1.67 and 1.19 mg/l, respectively.

Total organic carbon, which is a measure of the level of decay of vegetal matter and other wastes, ranged in concentration in the preserve from 4 to 27 mg/l and averaged 11 mg/l. Similar concentrations

(12 to 23 mg/l) are reported from sparse data from the Oklawaha and Withlacoochee Rivers in 1968 and 1969. In Florida, vegetation is abundant, and its decomposition and oxidation probably result in this background concentration. Organic carbon also occurs in many types of waste, including sewage effluent. Total organic carbon concentrations as high as 420 mg/l have been measured in canals in Dade County. Concentrations of this magnitude are indicative of pollution.

Much of the abundant vegetation eventually becomes incorporated into the sediment, where it represents a large potential reservoir of organic carbon, nitrogen, and phosphorus. In four ponds sampled in Big Cypress, the sediment (dry weight) had concentrations that ranged from 33.1 to 46.0 percent total organic carbon and from 2.51 to 3.0 percent total nitrogen.

Sparse data from the Upper St. Johns River basin indicate that total organic carbon and total nitrogen in sediment are similarly high in places. Concentrations of trace elements and heavy metals in the waters of the Big Cypress Preserve were generally below levels that are listed as the recommended upper limit for fish and wildlife.

Although components of the DDT family were the most commonly-detected pesticide, their concentration in the sediments of the preserve were significantly lower than those in the sediments of canals in nearby Broward County. The average concentration was 5.09 μg/kg (micrograms per kilogram) in the preserve and 62.91 μg/kg in the Broward canals. The average concentration of DDT derivatives in the water, however, was higher in Big Cypress, 0.07 μg/l (micrograms per liter), than in Broward, 0.02 μg/l. The high average in the Big Cypress is a result of three individually high analyses of water samples collected near areas

of human habitation or activity. Sediment concentration is a better indicator of pesticide contamination than water concentration because sediment samples become more nearly integrated over a period of time. The concentration in a water sample, on the other hand, may reflect only temporary and local contamination. Over the past several years there has been a shift to increased usage of organophosphorous pesticides in south Florida. No data are currently available as to their presence in the Big Cypress.

Water quality changes occur seasonally and diurnally in Big Cypress and are related to the natural hydrologic and biologic regimes. The seasonal recession of water levels triggers physical, chemical, and biological changes in water quality. During low water, diurnal fluctuations in dissolved oxygen are greatest as a result of the high concentration of organisms in the remaining water. During the day, plants produce excess oxygen by photosynthesis. Dissolved oxygen as high as 150 percent saturation was measured in one cypress pond in later afternoon. At night, dissolved oxygen decreases as photosynthesis ceases and respiration demands are met. Concentrations of dissolved oxygen may fall below 20 percent saturation (2 mg/l) before dawn. Fish kills sometimes occur at this time. Spring fish kills have been observed in the Tamiami Canal, centered in an area about 10 miles west of Forty Mile Bend and often spreading both east and west for several miles. These kills occurred during periods of low dissolved oxygen.

Despite the high fluctuations in dissolved oxygen, the overall water quality of the preserve, as determined from the base line data obtained in 1969-70, is good. Limited subsequent measurements indicate no significant changes in overall water quality in the ensuing years.

C. Land Cover

Land cover in the Big Cypress Preserve is primarily limited to natural vegetation, though the encroachment of exotic plants is a growing problem in some areas. Man-made intrusions consist of the airport training facility in the eastern part of the preserve and some small residential and commercial developments at Ochopee along the Tamiami Trail at the western edge of the preserve. Agricultural lands that existed prior to the establishment of the preserve are no longer cultivated. Some grazing, however, still occurs under existing permits in parts of the preserve.

The Geographic Information Systems field unit of the National Park Service has recently completed a land-use cover map for Big Cypress National Preserve. This map delineates the following fourteen vegetation associations: cypress domes, cypress strands, mixed hardwood-cypress strands, hardwood hammocks, pine forests, cypress prairies, shrubby hardwoods, hardwoods inside fire-scorched cypress domes, graminoid marshes (including sawgrass), herbaceous prairies, Melaleuca and Casurina stands, agricultural fields, oak/palm hammocks, and Serenoa thickets. To a large degree, the distribution of the natural vegetation reflects the seasonal availability of water, fire history, and prior disturbance. Because of the seasonal fluctuation in water levels, the area is rich in aquatic and water-tolerant vegetation. This vegetation is part of an ecological system that is compatible with cyclic fluctuations in water levels and adaptable to the natural catastrophies of fire, flood, hurricane, and drought.

Seasonal fluctuations in water levels also mean that land elevation is a controlling factor in the type of ecologic community in a

given location. Differences in elevation of 1 or 2 feet distinguish hardwood forest from prairie wetlands and marshes.

1. Types of Land Cover

Occurring at the higher elevations are the pine forests and hardwood hammocks. Although the species of vegetation differs in each, they have a common hydrologic characteristic in that they have a relatively short hydroperiod during which the land surface is inundated. For the pinelands, this hydroperiod is about 20 to 60 days; for the hardwood hammocks, it is about 10 to 45 days. Hardwood forests also occur as elongated strands that tend to follow lower land elevations. Land elevation within these hardwood forests, however, is often variable and includes areas that are inundated most of the year to those that are seldom inundated. For the most part, however, these forests are seasonally flooded for months. They consist of a mixture of many tree and scrub species. In many of these hardwood forests, cypress trees were dominant before logging.

Cypress forests are present in the form of both strands and sloughs. The cypress strands are associated with elongated depressions in the bedrock. The larger trees have been logged from most of the strands in the preserve. Frequently both cypress forests and hardwood forests coexist in strands. The cypress generally occur at the lower topographic elevations having hydroperiods that frequently exceed 250 days per year. Cypress domes exist in the more open prairie wetlands. These domes are small and localized and occur in either circular or elongated bedrock depressions with an overstory of pond cypress and an understory of ferns, spikerush, cocoplum, willow, and wax myrtle.

They formerly contained numerous bromiliads and orchids. Orchids particularly are now rare, having been largely removed by man.

Much of the preserve consists of either prairie wetlands or scrub cypress wetlands. These wetlands comprise grasses, sedges, and other herbaceous plants, with few trees. All are inundated at some time during the wet season, usually for months at a time but sometimes only for a few weeks during dry years, depending upon local land elevations. In general, though, the prairies with the shorter hydroperiods are more common in the northern part of the preserve; those with the longer hydroperiods cover large areas south of Tamiami Trail where they often merge almost imperceptibly with the sloughs and strands.

Only a very small part of the preserve is in coastal marshes and mangrove. These areas occur at the lower end of the drainage within the preserve.

2. Hydrologic Significance

Water levels in the Big Cypress Preserve are of major importance to the ecosystem because of the fact that a relatively narrow range in stage governs the complete range of plant communities in the fresh-water environment and the salinity balance in the estuaries. At any given location, the environment can range from fresh-water swamp to hammock forest within a range of average annual water levels of less than 3 feet. A dynamic but delicate adaptation of species to water levels prevails, and any abrupt and permanent changes of even a few inches in the water-level regimen can result in major changes in the ecology. This is clearly shown in the following three illustrations (Figures 8, 9, and 10).

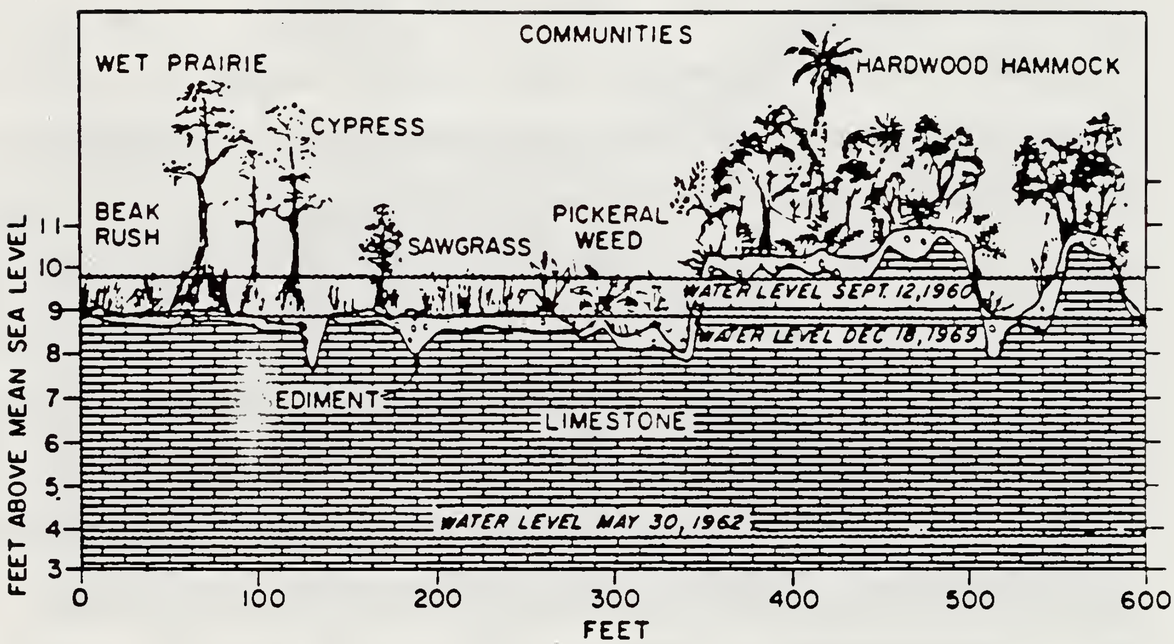


Figure 8. Vegetal transect in the Big Cypress National Preserve from a wet prairie into a hardwood hammock. (Source: U.S. Geological Survey)

As shown in Figure 8, the hardwood hammock forest is established on land above high water. These hammocks are seldom inundated, but many have small, shallow depressions that contain water, at least during the wet season.

Figure 9 depicts three distinct communities. The pine-palm-palmetto forest, although inundated for at least part of the year, occupies the higher elevations. A wet-prairie community grows where ground elevation is only inches lower than that of the pine-palm-palmetto forest. The cypress forest grows at the lowest ground elevation, as much as 2 feet lower than the pine forest. The cypress forests are inundated most of the year. They contain two distinct types of cypress: a small variety that grows in the shallower water, the scrub cypress, and a large variety that grows in deeper water. In profile the large-cypress community is bell shaped, with the tallest trees in the center and successively shorter trees toward the edges. Open ponds occur within some of the tree communities; these are vital to the survival of many plants and animals during drought.

A somewhat similar transect is shown in Figure 10. Again, the wet-prairie environment yields to scrub-cypress wetlands and, at a slightly lower elevation, to a large-cypress community in the form of a strand. Such strands, along with the ponds in the tree communities, are the last areas to become dry during the dry season; many contain water perennially except during extreme drought.

As shown in the three transects, local ground elevations generally vary less than 3 feet. Although the extremes of variations in water levels are about 6 feet, the normal range is about 3 feet. Thus, the seasonal fluctuations in water levels result in extensive, almost

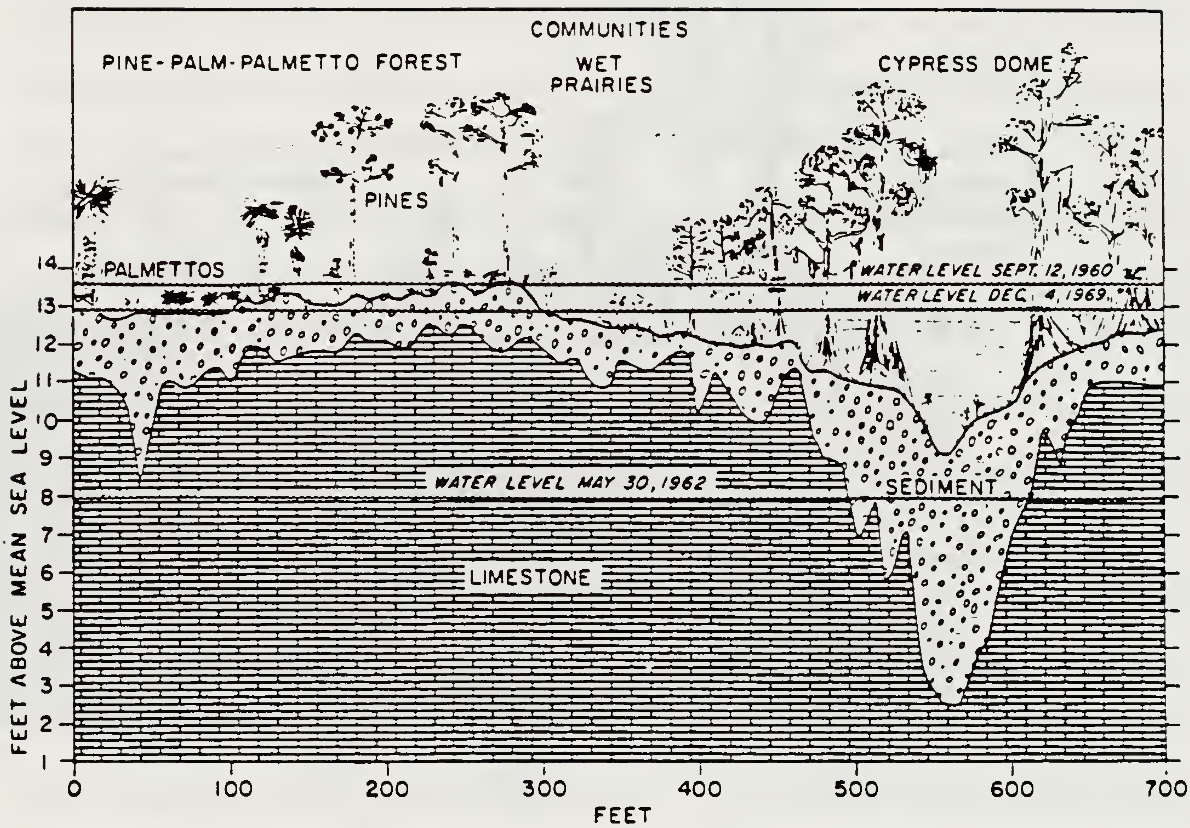


Figure 9. Vegetal transect in the Big Cypress National Reserve from a pineland forest into a cypress dome. (Source: U.S. Geological Survey)

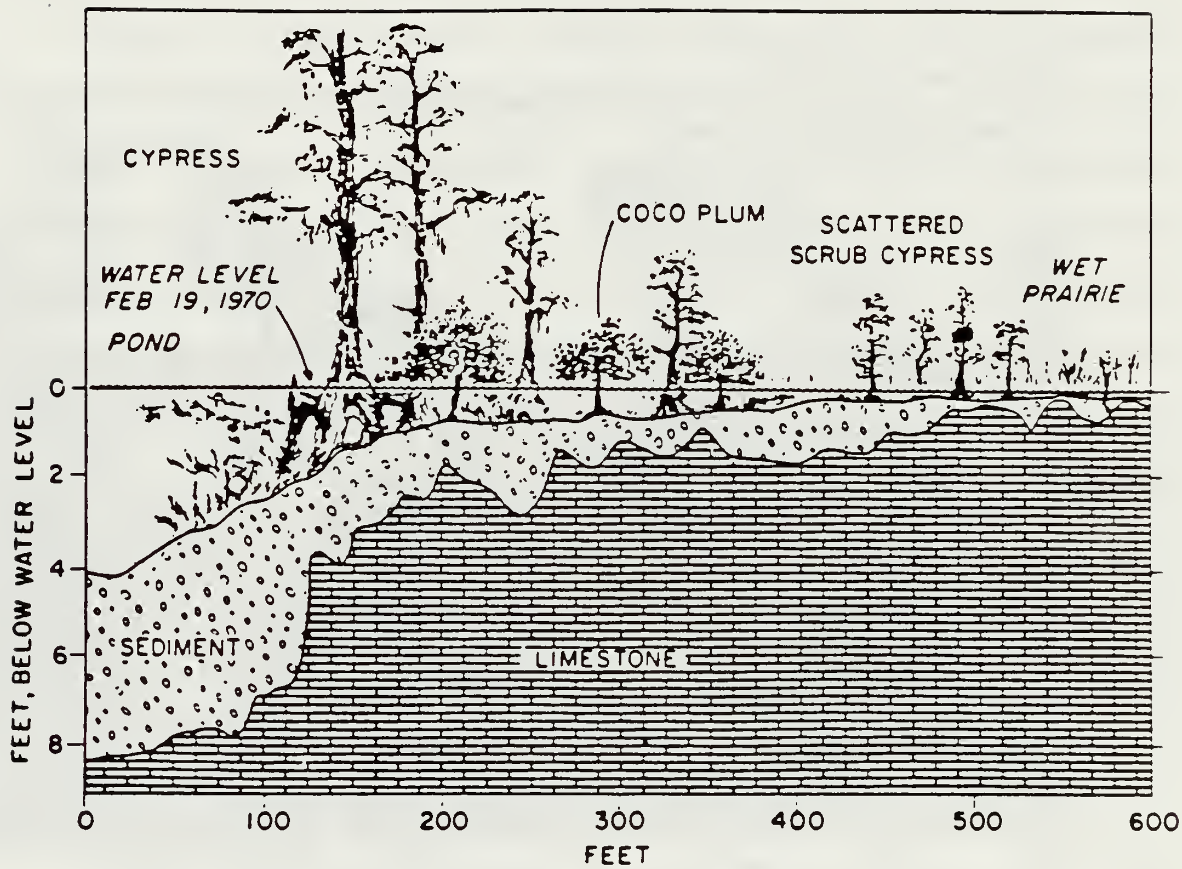


Figure 10. Vegetal transect in the Big Cypress National Preserve from a wet prairie into a cypress strand. (Source: U.S. Geological Survey)

complete inundation during the wet season and in localized concentration of water in the sloughs and ponds during the dry season.

The availability of food in the Big Cypress National Preserve is related to seasonal water levels. During the high-water period, abundant food is produced in the flooded areas. Periphyton mats, growing as thick as 2 inches on submerged vegetation and on the flooded land, provide an abumdant source of food for fish and invertebrates. During this period, these populations increase significantly. During the unseasonably high-water period between December 1969 and March 1970, fresh-water dominant species trapped in a cypress slough increased from 31 specimens per trapping, with a total wet weight of 3 grams, to 123 specimens per trapping, with a total wet weight of 10 grams. This corresponds to the patterns of increase that have been measured in the Everglades during comparable wet periods.

As water levels decline during the dry season, aquatic populations are forced to concentrate in the remaining water in the ponds and sloughs. Densities as high as 5,000 fish per cubic meter of water have been reported. The biomass concentrated in the ponds and sloughs during low-water periods is a rich source of food for larger animals, especially fish, snakes, alligators, and predatory birds. Large flocks of wading birds depend mostly upon this concentration of fish for their food. As many as 350 wading birds have been observed feeding in one small cypress pond less than 150 feet in diameter.

The estuarine environment is equally responsive to change in the fresh-water outflow from the inland areas. This fresh-water outflow mixes with the salt water in the estuaries to provide brackish conditions required by many marine and estuarine species during some or all phases of their development.

III. HYDROLOGIC ASSESSMENTS

A. Significance of Watershed Boundary

The identification of the Big Cypress National Preserve as essentially a self-contained hydrologic unit greatly simplifies the preparation of a General Management Plan and a Minerals Management Plan for the preserve. The integrity of the water resources can be maintained under the direct control of the National Park Service.

The almost imperceptible low ridge that defines the drainage boundary between the Big Cypress and Everglades drainages is undoubtedly inundated at times during most, if not all, years. Because of this, there is likely some minor movement of water back and forth at times in response to local rains in the vicinity. However, the persistent flow patterns observable in Mullet Slough, just north of the ridge, indicate clearly that the water in this slough moves in a generally eastward direction toward the Everglades. This eastward movement effectively isolates the surface-water hydrology of the preserve from development or land-use changes northeast of the preserve. This is especially significant in light of recent newspaper reports of increased interest in the expansion of the citrus industry north of the preserve. The problems of pesticide contamination and water use for irrigation would affect the Everglades drainage rather than that of Big Cypress.

However, the interconnection of the Okaloacoochee Slough with the East Hinson Marsh will require consideration in the planning process. Major changes in land use in the drainage basin of the slough could provide water of deteriorated quality to the northwest corner of the preserve. No actual data are available on flows through the culverts in the Bear Island road, which effectively separates the Okaloacoochee drainage from the preserve. Inasmuch as the road is a main access to

the oil fields in the preserve, it is likely to remain for a substantial length of time. Its present function, both as a road and as an effective drainage divide, will require careful evaluation and consideration in the preparation of the General Management and Mineral Management Plans for the preserve.

A small area along the southeastern corner of the preserve forms the extreme western boundary of the Shark River Slough, a major drainage of Everglades National Park. The quantity and quality of water in this area may be influenced by water releases made to Everglades National Park through the S-12 structures. This also should be considered in developing the management plans.

B. Land Cover

Land cover in the preserve is limited primarily to natural vegetative cover except for small, isolated, developed areas primarily along U.S. Highway 41. These areas include the Training and Transition Airport at Fifty Mile Bend and the pads and roads associated with oil exploration and development. The preserve itself is not subject to urban or industrial growth, but will be under considerable pressure in the foreseeable future from further oil exploration and development. Hence development and land-use, particularly changing agricultural and urban patterns, will not be a direct threat to the water resources of the preserve.

The prime areas of land cover of concern to the water resources of the preserve are the sloughs and strands (Figure 11). Consisting primarily of cypress forests and mixed hardwood forests at the lower elevations, they provide the broad drainage courses for water movement through the preserve, and almost exclusively provide water during the dry season to sustain fish and wildlife populations.

Figure 11. Strands and sloughs in the Big Cypress National Preserve. (Source: National Park Service)

C. Water Regimen Modifications

The natural water regimen of the Big Cypress National Preserve has been modified significantly by man-made structures. Most significant are the canals and roads which interrupt or intercept the natural drainage.

1. Turner River

The Turner River Canal was constructed specifically to provide fill during the construction of the Turner River Road in 1960. The canal originates about 2 miles north of Alligator Alley at the southern end of the East Hinson Marsh, and enters the Turner River about 1 mile south of the Tamiami Trail (Figure 12). As such, it provides a direct hydraulic connection between the fresh-water uplands of the preserve and the saline estuaries within Everglades National Park. It also affects its adjacent areas by altering the ground-water table, disrupting natural surface flow patterns, and reducing river stages and flow rates in the upper portions of the Turner River. Measurements made during the dry season in 1980 indicate that ground-water levels were lowered by about 1 foot to a distance of 600 feet on either side of the canal. The total effect probably extended one-quarter to one-half mile on each side of the canal, affecting several thousand acres of wetlands. The patterns of surface flow are altered as the roadway restricts the natural south-western movement of flow and shunts it southward in the canal. Except for the two 3-foot diameter culverts located approximately 1 1/2 miles north of Tamiami Trail, the normal southwestward flow of surface water is intercepted by the canal to about 1 mile below the Tamiami Trail. As a result of the canal, there is reduced flow in the natural channel of the Turner River from the Turner River Road to the point where the canal enters the river, a distance of about 3 miles.

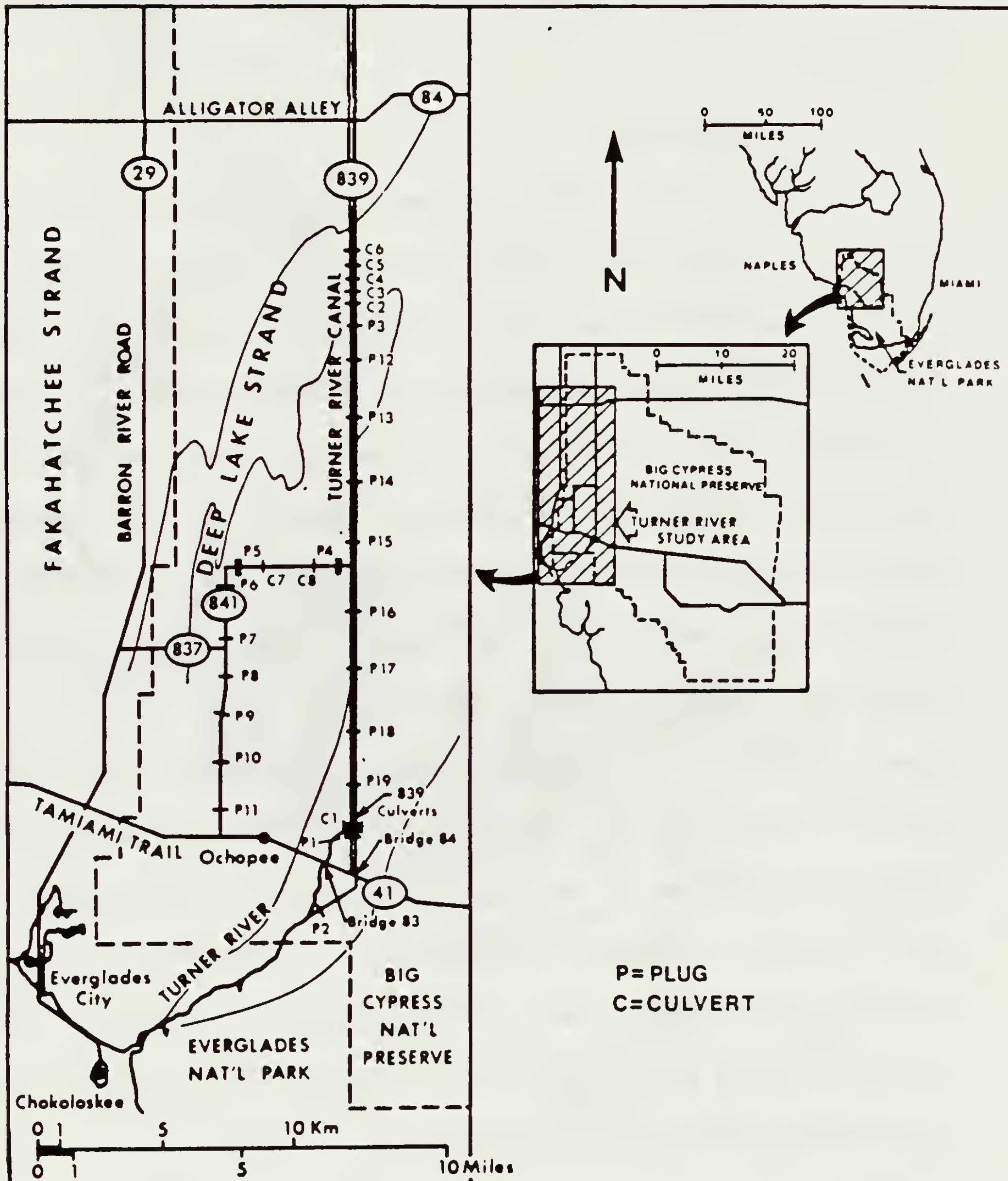


Figure 12. Proposed restoration of the Turner River. (Source: National Park Service).

Acting under the broad authority of National Park Service Organic Act of 1916 and PL 93-440, which created the preserve, the National Park Service has proposed a two-phase plan to restore the natural flows of the Turner River. Under Phase 1, the natural flow of the Turner River would be restored by plugging the canal just south of the existing culverts under the road, and placing additional culverts under the road to facilitate flow to the natural channel. The canal would also be plugged at its lower end to prevent salt water intrusion into the then-unused section of canal. As a result, flows at Bridge 83 over the natural Turner River channel would remain above zero for up to 11 months of the year, compared with current flow conditions that now average zero or near zero for 6 months of the year. Also, over half of the time, river stages would increase from a 2.0-foot minimum level to 2.75 feet. Flow would likely occur at Bridge 83 as much as 88 percent of the time rather than the present 38 percent. Flows at Bridge 83 currently exceed 45 cfs 10 percent of the time. After Phase I restoration, flows would be expected to exceed 340 cfs 10 percent of the time. Three 72-inch corrugated metal pipe culverts have already been purchased; installation is awaiting funding for completion of Phase 1.

Phase 2 proposes four additional restoration projects for the Turner River. These relate to the Deep Lake Strand, the ground-water levels along the Turner River Road, and the surface flows from north to south along State Route 841.

2. Releases from Conservation Area 3-A

A recent agreement between the National Park Service, the South Florida Water Management District, and the U.S. Army Corps of Engineers has resulted in a two-year experimental program modifying the manner in

which water is released from Conservation Area 3-A to the Shark River Slough in the Everglades National Park. Under the agreement, both amounts and timing of releases from the conservation area will be determined primarily on the basis of rainfall rather than on arbitrary regulation schedules, and will incorporate periods of transitional flows rather than abrupt, sudden changes. Approximately 55 percent of the water is scheduled for release at the eastern end of the conservation area, and 45 percent at the western end. The releases through the western end will affect the preserve.

Structures S-343A and S-343B (see Figure 1) have a design capacity of 400 cfs, which is equal to that of the S-12 structures across Tamiami Trail east of Forty Mile Bend. Under the experimental program, S-343A and S-343B will be used only if the S-12 structures cannot convey the allocation of water to the Shark River Slough or if water levels in Conservation Area 3-A reach exceptionally high stages. Currently, there is no agreement between the South Florida Water Management District and the farmers and residents of the East Everglades area regarding release schedules to the area. If these releases cannot be made through S-333 in the eastern end of the conservation area, the total allocation will be released through the S-12 structures, and if necessary, S-343A and S-343B. Negotiations are now under way with the residents and farmers in the East Everglades area. The outcome of the two-year experimental release program is dependent upon demonstrating the practicability of the program and particularly upon resolution of differences among various interest groups now engaged in negotiation and potential litigation.

Releases, however, would affect only a small area of the preserve. The releases through S-343A and S-343B would enter the Tamiami Canal and be distributed to the preserve through seven existing bridges (each 14 feet wide) in the 4-mile stretch of Tamiami Trail northwest of Forty Mile Bend, and through the 87-foot-wide bridge at Forty Mile Bend. Assuming an equal distribution of water through the bridge openings, nearly half of the water would enter the preserve in the vicinity of Forty Mile Bend.

Infrequent releases (once every 3-5 years) would tend to extend the hydroperiods of both scrub-cypress wetlands and prairie wetlands in the southeast corner of the preserve for brief periods following these releases. More significant would be the effect of the additional fresh-water inflow to the estuaries of Everglades National Park in the area below the preserve. However, increases in the hydroperiods resulting from regular and persistent releases would likely result in some modification of composition of the affected ecologic communities north of the Loop Road, due to the present impounding effects created by the road.

3. Loop Road Drainage

The current bridges and culverts in the Loop Road are inadequate for transmitting the flow of water southward, and the road itself is regularly overtopped during the wet season. Although there are three 57-foot wide bridges and seven metal pipe culverts in the eight-mile stretch west of Forty Mile Bend, differences of six inches or more have been observed in water levels above and below the road. This condition also exists to some degree along the rest of the road. Improvement of the road to an all-weather status will require both raising the road

elevation and installing many more bridges and culverts to eliminate the damming effect of the present road and promote more normal flow of water.

4. Levee 28

Levee 28, extending northward from the Tamiami Trail, forms the eastern boundary between the Big Cypress and Everglades drainage systems. It was constructed in the 1960's to provide flood control and to protect the present jetport site which at that time was under consideration. The levee is approximately 13 miles long with a 1½-mile-long tieback extending westward at the northern end. The borrow canal along the upper five miles of levee is on the east side; for the remainder of the levee, it is on the west side. There is a regulated culvert at this changeover location where water can be released in either direction between the Big Cypress and the Everglades drainages.

In response to a seven-point program recommended by the National Park Service to improve flow of water in both the Everglades and the Big Cypress Swamp, the Corps of Engineers cut three openings in the tieback levee and two in Levee 28 north of the jetport site. Plugs were also placed in the borrow canals to inhibit drainage. These openings have been ineffective in promoting transfers of water between the Big Cypress Swamp and the Everglades. According to James H. Hartwell, a consulting hydrologist in Miami, Florida, there is no current need for the levee, and removing the levee completely would have little or no effect on either Big Cypress or the Everglades. Conservation Area 3-A east of the levee currently receives all of its water from rainfall; there has been no significant inflow from the north since the regulation of Lake

Okeechobee and the establishment of the conservation areas. Removing the levee would simply provide for a more normal and natural flow system.

5. Pace's Dike

Pace's dike is a low dike or levee completely surrounding an area of 1,340 acres located south of the Loop Road. The dike was built before acquisition of the land in the Big Cypress National Preserve with material from a borrow canal just inside of the dike. The owners' intent was to reduce water levels within the diked area by pumping from the borrow canal sufficiently to allow occupancy of the area. Except for its location in the Gum Slough, it is of little hydrologic significance. Any limited effect could easily be negated by simply breaching the dike along both the northern and southern sides.

D. Oil and Gas Operations

The oil and gas operations in the preserve present some of the most difficult issues in management of the water resources. Both relate to uncertainties: the intent and location of future development, and the uncertainty of a major catastrophe. The first can be speculated or hypothesized to some extent; the second, with an extremely low probability of occurrence, is always present. The operations appear to have the potential for large-scale expansion.

Several regulatory agencies have jurisdiction and interest regarding the hydrologic aspects of oil and gas activities in the preserve. Among these are the Florida Department of Natural Resources Bureau of Geology, the Florida Department of Environmental Regulation, Collier County, the U.S. Army Corps of Engineers, the South Florida Water Management District, and the National Park Service. The National

Park Service also formally consults with the federal Bureau of Land Management for technical review of casing and cementing programs for proposed drilling operations to ensure adequate aquifer protection.

Of interest in this process is a cooperative forum provided by the Big Cypress Swamp Advisory Committee. The committee consists of the State Geologist as Chairman, a representative from organized conservation groups, the executive director of the Florida Petroleum Council, and a hydrologist and a botanist unanimously selected by the other three members.

Currently about 5,000 barrels of oil are produced daily, with about 3,000 barrels produced at the Raccoon Point field and about 2,000 barrels at the Bear Island field (Figure 13). Both fields lie along the Sunniland Trend which extends through the northeastern part of the preserve. Exploration along the Sunniland Trend began in the 1930s, but discovery was not made until 1943. The discovery well for the Bear Island field was drilled in 1972. Exploration locations in this field were governed by an existing tram road formerly used for cypress logging which provided ready access to the area. The field consists of 22 producing wells and 8 injection wells on small pads that usually contain one or two wells. Produced oil is transported from Bear Island via pipeline.

Eight of the current wells lie south of the Okaloacoochee Slough, with access over the Bear Island Road, a former tram road that has been upgraded to an all-weather road. This road is considered to be an effective drainage divide between the Okaloacoochee Slough and the preserve to the south.

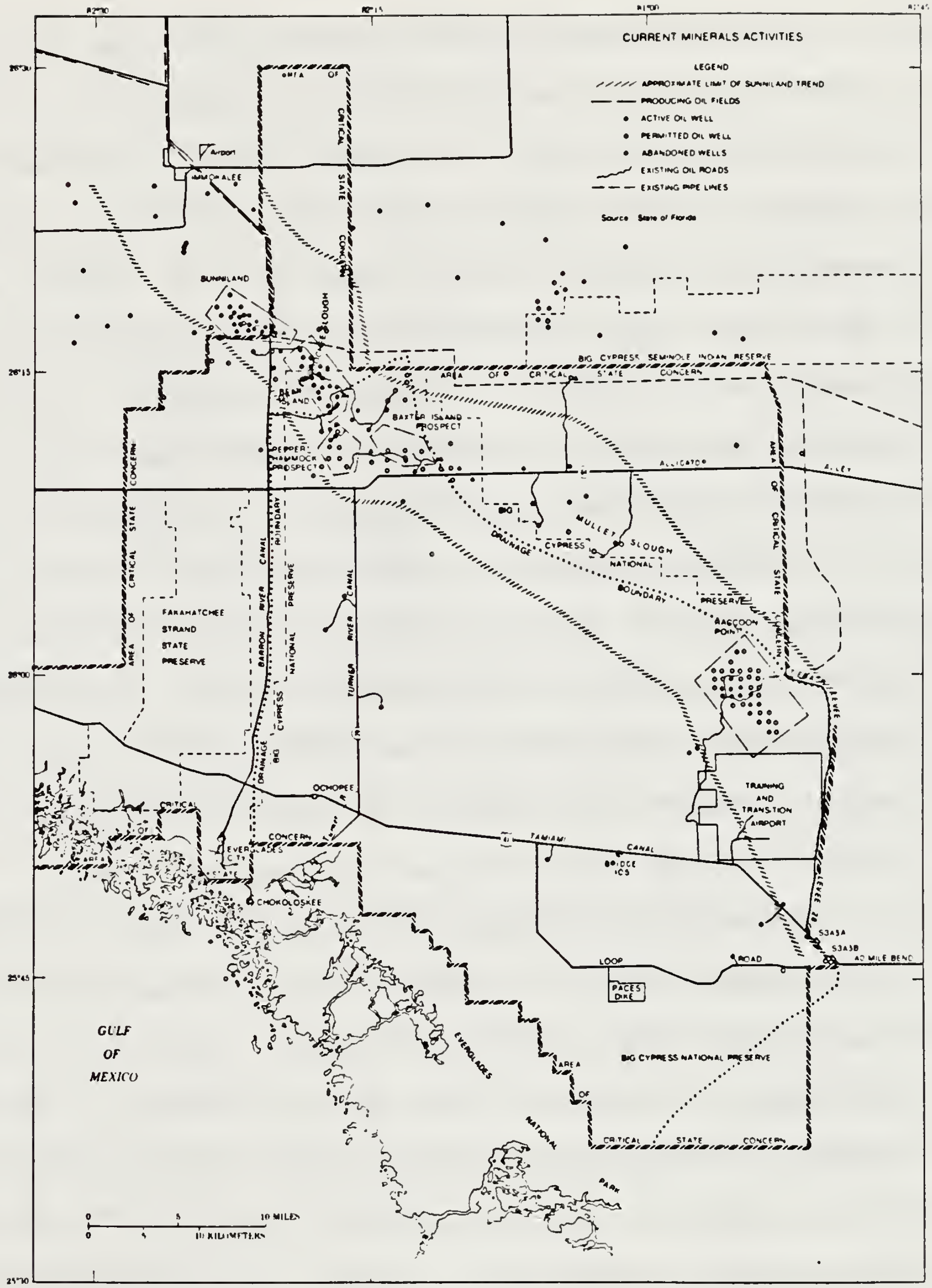


Figure 13. Oil and gas activities in and near the Big Cypress National Preserve. Well locations represent down-hole locations. In most instances, several wells have been directionally drilled from each pad. (Source: State of Florida)

The Raccoon Point field currently consists of 13 producing wells drilled diagonally from four pads, each averaging 1,000 feet by 200 feet and covering 24.76 acres. Currently, a total of 18 wells have been permitted; however, plans have been submitted for the construction of a 6-well fifth pad and a 2-well expansion of an existing pad. Current operations involve 13 1/2 miles of all-weather road, with one additional mile to be constructed if a fifth pad is approved. The road is 20 to 25 feet wide and is culverted to permit normal flow. There is a possibility that even further expansion of this field will occur.

A likely location for further development is the Pepper Hammock prospect south of the Bear Island field. In 1978 a potential producing well, considered to be the discovery well for a Pepper Hammock field, was drilled. Plans have been received for the drilling of confirmation wells to verify this discovery and further delineate the field. This field, if proven, will extend into the East Hinson Marsh.

The successful oil operation in South Florida by the Exxon Company has heightened interest in further seismic and exploration drilling by Texaco, GECO, Shell, and other companies. Interest is not limited to the Sunniland Trend, but also extends considerably south of it. In addition to the possibility of gas fields south of the Sunniland Trend is the prospect of oil at other depths. There are 14 known zones in the stratigraphy that show oil, including a so-called "Trinity-C" zone that also contains sour gas, a potential hazard for explosion and fire. Development of this zone could require severely-restricted operations both on-site and in the vicinity because of the hazard.

Currently there are 118 oil and gas permits that have been issued by the State of Florida for the preserve. Some 62 wells have been drilled. As the surface owner of the Big Cypress Preserve, the National

Park Service has established a regulatory procedure for permitting operations. In practice, it requires the oil company to notify the surface owner of its application for a State permit and to obtain a permit from the National Park Service to stake both the access area and the drilling site. A field inspection then evaluates possible alternative access routes to minimize environmental impacts, and a route is negotiated. If the proposal is accepted, a detailed plan of operations is developed by the company. If this plan is accepted by the National Park Service, a notice of its availability is published in the Federal Register, and consultations are held with the Fish and Wildlife Service regarding endangered species. After appropriate revisions of the plans are completed, an environmental assessment is made. If there is a finding of no significant impact, authorization is granted to proceed. The process normally takes six to ten months, but has taken as long as two years.

Operational oversight, consisting of monitoring and compliance, has been limited in the past, with little effort toward compliance. The process is much improved, but particularly lacking are criteria for reclamation work against which to measure compliance. Current operations are well-conducted and well-supervised and inspected. Recently, several new operational procedures have been installed to further minimize the potential for impacts. A new drilling fluid containment system is now being tested in which metal containers are used to store fluids from drains and from drip pans under drilling equipment. Reserve pits will no longer be utilized; instead, a closed recycling system will now be used. This reduces the pad size by one-third to one-quarter, and mitigates the leaching of high-chloride water from reserve pits and subsequent pit reclamation.

Oil and gas operations to date have had minimal to very limited impact on the water resources. Pad locations and roads are offset to avoid hammocks, strands, and sloughs insofar as feasible. In areas of perceptible flow patterns, pads are oriented to provide minimal blockage. Roads are culverted to insure normal sheet flow. Eleven-Mile Road, leading to Raccoon Point field, was designed in 1981 by Exxon engineers with culverting based upon sound hydrologic considerations. This culverting plan was modified after field inspection. Care is exercised in the drilling process to insure isolation of the shallow aquifer from the Floridan and lower aquifers; abandoned wells are plugged to insure future isolation. Spill contingency plans exist, and equipment is on ready status at all times. An example of rapid response is seen in an oilspill along the Eleven Mile Road on November 5, 1983, when a tanker truck overturned, spilling some 60 barrels of oil into the adjacent environment. Cleanup started immediately, with a containment boom limiting the area of involvement to 100 yards. Spilled oil was removed, contaminated road fill removed and replaced, and contaminated soils removed. No reclamation procedures were instituted. The area currently is recovering, with both spikerush and sawgrass present.

Salt spills, mostly from pin-hole leaks in pipeline, are localized and have limited effect on water quality. The largest problem, that of leaching from a pit at Raccoon Point, affected approximately two and one-half acres.

At the current rate of development, oil and gas operations in the preserve will have only minimal local effect on the water resources if surveillance is employed regularly and compliance with regulations is enforced. However, an accelerated rate of development could significantly stress the water resources in local areas.

E. Proposed Interstate Highway I-75

The construction of Interstate Highway I-75 will affect a twelve-mile long corridor in the Big Cypress National Preserve eastward from State Route 29. Project plans propose building two additional lanes on the north side of the existing State Route 84 between the present levee and the borrow canal. An environmental impact statement was prepared in 1972 and is now being reviewed to determine if a supplemental statement is necessary. Final plans await resolution of comments on the status of the 1972 environmental impact statement.

The proposed interstate highway plans prepared by Greiner Engineering Services, Inc., include three additional 10-foot by 5-foot box culverts and two 48-inch round pipe culverts within the preserve. Currently there are three bridges and three culverts in this section, all located east of the Turner River Road. There are no drainage structures between State Route 29 and the Turner River Road. Plans for I-75 include three box culverts and one pipe culvert in this section, and two additional pipe culverts in the East Hinson Marsh just east of the Turner River Road.

The additional structures were determined on the basis of computed flood flows based upon drainage areas and existing flow data. The designations of the four sub-areas of drainage for the section of road in the preserve appear reasonable; the methodology for computation of the peak flows is standard. No attempt was made to verify the numbers of this assessment. Of significance is the proposal in the present plans to insert plugs in the borrow canals which would essentially isolate flows from each of the four sub-areas by inhibiting lateral movement of water across the imperceptible drainage boundaries. This could at times cause an inbalance in flows, especially during the wet

season when heavy rainfall from local storm events builds mounds of water that flow radially as they disperse.

The present plans propose obtaining the necessary fill material for the roadway by widening and deepening the existing borrow canal as required. Although some recent concerns have been expressed that deepening the borrow canal could introduce water with higher chloride concentrations into the surface waters, this problem is of concern only near the coastal areas. It will not be a problem in the vicinity of the preserve, according to the U.S. Geological Survey.

Also included are plans for acquisition of an additional 125 feet of new right-of-way on the south side of the existing roadway for water management purposes. The plans propose a new canal in this right-of-way, possibly eight to ten feet deep and 40 to 80 feet wide, to distribute the water from the culverts and bridges laterally. Ostensibly, this canal would prevent any damming effect of the roadway and would distribute flow uniformly downstream.

There is some question as to the efficacy of the drainage proposal. During periods of high water when the water levels are above ground, the entire flow system is in a backwater condition; therefore, the proposed canal would have little or no effect on the getaway conditions of the flow below the roadway.

Given the hydraulic characteristics of sheet flow that exist in the preserve and the response to local rainfall, neither the blocks in the canals nor the proposed canal on the south side of the highway appear necessary. Of prime importance is the provision of adequate culverting under the highway to permit the passage of water, with minimal differences in water levels above and below the highway.

F. Off-road Vehicles

There is substantial use in the Big Cypress National Preserve of off-road vehicles (ORV's) such as all-terrain vehicles (ATC's), air boats, and swamp buggies. Used primarily for access to the 300 or more camps in the preserve and as means of transport for hunters, they provide the only means of ground transportation in the preserve. Their use has long been a center of controversy.

Data on ORV use in the preserve was obtained by the South Florida Research Center, Everglades National Park, between March 1978 and March 1980. During this period, swamp buggies with their high chassis and oversized tires were most prevalent, comprising more than half of all ORV's. Airboats and small, three-wheel ATC's shared the balance in about equal proportions. During hunting season in November, 1978, about 540 swamp buggies were observed in the preserve.

The survey also determined that ORV use follows a highly seasonal pattern, with the greatest use occurring at the beginning of the hunting season in early November. Use decreased to much lower levels for the remainder of the approximately two-month-long hunting season, and was very low during the rest of the year. As would be expected, weekend activity was much higher than that on weekdays.

Only one definitive study exists on the effect of ORV's on the water resources. In this study, an extensive survey was made of water flows at ORV trails. Although the study concluded that flows likely increased along ORV trails at least during low-water periods, it also pointed out that major trails are both widely scattered and are to a large extent on higher ground. The study concluded that the impact of these trails on the regional water resources is essentially negligible.

The study also concluded that localized impact of continued flow in the trails, after water movement in the local area had ceased, could be minimized by creating occasional ridges across the trail that are level with the surrounding terrain. It is likely that such ridges now exist naturally where the trails cross exposed hard limestone bedrock.